Nephelometric detection unit with optical in-process control

The present invention relates to the field of the use of automated measurement systems in analysis and in in-vitro diagnosis. In particular, the apparatus described enables automatic quality control and validation of characteristic process engineering parameters, in particular characteristic optical parameters, during the measurement of scattered light signals.

An increasing demand for sensitive optical detection methods which can be used in fully automated analyzers appertaining to laboratory diagnosis has evolved in recent years.

In addition to the requirements made of the measurement method, such as sensitivity, resolution or dynamic range, the high degree of automation means that, in the same way, requirements are also made of the automated testing, setting and, if appropriate, readjustment of the parameters of the measurement method used. Therefore, quality control and validation measures must likewise be ensured by automated methods.

In the different methods of analysis, the testing and securing of valid results are characterized by varying degrees of difficulty. While testing is possible in absorption spectroscopy, for example by using officially calibrated standards, this is not provided for methods of scattered light spectroscopy. In the method of forward light scattering, in particular, which utilizes angles or angular ranges near the incident beam of the light source, simultaneous measurement of characteristic optical parameters within the beam path is difficult on account of the mechanical structure. Therefore, characteristic optical

parameters, such as intensity, wavelength, pulse length or noise component of the light source used, and with the use of a vessel (cuvette or the like) which serves to accommodate the material to be measured and is briefly inserted into the beam path, can frequently be determined only with the aid of an additional relative standard. However, the necessity of using non-standardized test media gives rise to further fault sources which do not allow control over a relatively long period of time in situ and do not allow an unambiguous conclusion to be drawn about the property of the instrumental conditions.

In scattered light apparatuses, high-purity solutions such as toluene, for example, are used in the majority of cases for reference measurements. Measurement of the angle-dependent scattered light characteristic produces a profile and thus a measure of quality for the apparatus used.

On the one hand, the use of such liquids is problematic for reasons of safety and, on the other hand, carrying out the measurements described above is time-intensive and complicated in terms of laboratory technology. For these reasons, these methods cannot be used for application in automated analyzers. On the other hand, if a corresponding material to be measured which generates scattered light is not present, no measurement signal can be generated and thus no conclusion can be drawn about the quality of the method under the current operating conditions.

If, consequently, a material to be measured which generates scattered light is used, then it will generate a signal which differs from measurement to measurement, depending on its composition, its structure and the procedure for its use. Simultaneous validation of the measurement system is thus precluded.

These considerations also apply in a similar manner to methods in which the measurement signals are generated initially within the material to be measured, such as, for example, in the case of fluorescence or chemiluminescence reactions.

In the arrangement used most for scattered light measurement, the scattered light is detected under an angular range around 90° with respect to the direction of the incident beam. Separation of the incident light from the scattered light is particularly easy to achieve as a result. On the other hand, choosing a larger solid-angle range and utilizing angles or angular ranges around the forward direction of the incident light make it possible to achieve higher intensities of the scattered light, as a result of which an arrangement can be constructed in a technically simpler and more cost-effective manner. The proportion of scattered light at angles around the forward direction is particularly high precisely for the measurements (which are striven for in accordance with the present description) on organic macromolecules for use in human in-vitro diagnosis. In addition, use is made of the effect of increasing the intensity of the scattered light by the principle of particle enhancement. The dependence of the scatter signal on the particle size is the most favorable for the case in which the scattering particles are of an order of magnitude which corresponds to the order of magnitude of the wavelength of the incident light. This produces a preferred arrangement which makes it possible to utilize these components for the measurement. Fundamental considerations and calculations concerning the theory of scattered light are contained in the appropriate textbooks. The following may be mentioned here by way of example: H.C. van de Hulst (Light Scattering by Small Particles, Dover Publications, Inc. New York, 1957, 1981) and C.F. Bohren, D.R. Huffman (Absorption and Scattering of Light by Small Particles,

J. Wiley & Sons, New York, 1983). Given further knowledge of the properties of the material to be measured which is to be examined, discrimination of the material to be measured into magnitude classes can be achieved by selection of one or more angular ranges.

The apparatuses used in automated laboratory diagnosis are frequently constructed from, these being known per se to a person skilled in the art, movable units (e.g. rack, carousel, rotor or the like) for accommodating a multiplicity of vessels for sample or reagent liquids and the vessels for accommodating and passing through the material to be measured (cuvettes). In the event of using a rotatable unit for the positioning of the material to be measured, the cuvettes, in dependence on their requirements imposed on the measurement recording, are guided cyclically past a stationary position of the measurement unit. When scattered light measurements are carried out, the resultant scattered light is produced by the material to be measured in a cuvette, said material being introduced into the beam path. This means that changes can be produced by different positioning of the material to be measured.

Therefore, controlling the position of the cuvette is advantageous for controlling the intensity of the scattered light produced by the material to be measured. This possibility is achieved according to the invention by virtue of the independent control of the structure of the measurement unit (beam path) including the control of the type, structure and position of the cuvette without the use of a material to be measured which produces scattered light. The position thereby determined can be used for the synchronization of the measurement signal.

Consequently, the present invention was based on the object of finding a method which makes it possible to control the properties of a method for measuring

forward light scattering without the necessary use of a material to be measured which produces scattered light.

It has now been found that this object is achieved by means of an arrangement of the measurement unit in which the directly transmitted light is measured by a suitable detection device and, at the same time, the scattered light that is produced is detected.

For this purpose, a structure has been developed which makes it possible to measure the scattered light produced under angles not including 0° and the light transmitted under angles around 0°.

In particular, one aim of the method described is to carry out the control and validation of the beam path and the components used, such as the light source, the optical components of lenses and diaphragms and the properties brought about by the moving accommodating vessels of the material to be measured (cuvettes). Testing and control are likewise possible for the cuvette, which is situated in the beam path only during a measurement interval.

The arrangement described according to the invention can consequently be used as in-process control in automated analysis.

The arrangement of the apparatus according to the invention is elucidated with reference to the following figures:

Fig. 1: principle of previous analysis methods,
Fig. 2: structure with detection of the transmitted and scattered light,
Fig. 3: structure of the scattered light diaphragm,
Fig. 4: position of the detection unit within a cuvette wheel,

Fig. 5: diagrammatic representation of the intensity of the scattered (I) and transmitted (E) signal as a function of the cuvette position (x).

Figure 1 diagrammatically shows the principle of the previous method: a light beam 3 emerging from a light source 1, 11 passes through a lens system 2 and one or more diaphragms 4 to impinge on the measuring space 5; after passing through a lens system 6, the directly transmitted light from the light source 1 impinges on a diaphragm 7, which acts as a light trap. The light not extinguished by the diaphragm 7 is projected through a lens system 8 onto the detector 9 and measured by means of 10.

Figure 2 shows how the invention augments the method. If, in accordance with Figure 1, an accommodating vessel 12 with a material 13 to be measured which produces scattered light is positioned at the position 5, the measurement beam 3 penetrating said material to be measured, then a characteristic, angle-dependent scattered light distribution 14 is produced in dependence on the material to be measured. This distribution is detected by the aperture of the lens system 6 and 8 and passed to the detector 9. The light impinging on the region of the diaphragm 15 is detected by a further detector 16 and likewise measured. This component is composed of the component of the directly incident light from the light source and, given the presence of a material to be measured which produces scattered light, of the impinging scattered light fixed under the acceptance angle of the detector.

If the intention is to achieve a specific intensity at 16 for a cuvette 12, then this intensity can be detected and readjusted by measuring the intensity, without a material to be measured which produces scattered light, by means of the feedback system 17.

This affords the possibility of being able to carry out the scattered light measurements under respectively constant intensity conditions.

Possible configurations of the diaphragm 15 are shown by examples in Figure 3 a-c. The plan views in Fig. 3 a-c comprise the diaphragm 15 with an outer holding ring 21, an annular diaphragm 18 and one or more webs 20 for retaining 18.

The inner diaphragm 18 is designed as a perforated screen for allowing the directly transmitted beam component to pass. It may have further mounts for beam deflection and launching of the light into a glass rod or optical waveguide 23 and a detector 24 situated at the end thereof.

Figure 3 d-e shows the diaphragm 15 in a side view. The measurement beam 2 is coupled into a light guidance unit 23 with the aid of a beam deflection arrangement 15 and a special optical arrangement 26, 27. The detection can be carried out in a manner locally separate from this unit.

Figure 4 diagrammatically shows the incorporation of a detection unit within a rotatable mount (rotor system) 28 for accommodating the cuvettes 29. When the rotor rotates through the positions 1, 30, cyclic measurement is effected, the interval of this measurement being fixed by the speed parameter of the rotor. In the case of the measurement principle according to Figure 1, a signal can be measured and evaluated only when the cuvette contains a material to be measured which produces scattered light.

Figure 5 represents the fundamental profile of the signals generated by extinction E or scattering S as a function of the cuvette position. In this case, the type, composition and position of the cuvette have a

major influence on the level and waveform of the measurement signal. While the scattered light curve 32 can be produced only with a corresponding material to be measured, the curve of the component E produced by extinction can be measured even with cuvettes which are empty or filled with a non-scattering material to be measured, whereby independent determination of the position can be achieved.

The method according to the invention is of fundamental importance and can be used for any scattered light measurement. The scattered light measurement of biological macromolecules for determining concentration in the so-called nephelometric method is of particular importance.